Nest material preferences among European Starlings (*Sturnus vulgaris*) with a focus on feathers and anthropogenic materials

By

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Abstract

Avian nests provide critical shelter for offspring and differ in structure according to the species. They typically consist of natural materials such as dried grass, feathers from other species, and anthropogenic materials woven into them. The European starling (*Sturnus vulgaris*) is an urban-thriving cavity-nesting species. Their nests consist of both natural and anthropogenic materials taken from the surrounding area. Anthropogenic materials have been shown to reduce fledging success in certain species. Passerine research has previously revealed birds prefer unpigmented (white) feathers over pigmented feathers to incorporate into their nest, although a mixture of both may be present. Studies have demonstrated that unpigmented feathers result in greater hatching success. Along with that, the amount of feathers within a nest is positively correlated with growth rates among nestlings. Nests within nestboxes occupied by starlings in 2021 at Saint Mary's University in Halifax, Nova Scotia were examined after fledging to document the amount of anthropogenic materials and feathers among them. Of these, 16 nests were collected from early broods, and 22 from late broods. The amount of anthropogenic materials and feathers did not differ between early and late broods. Brood condition tended to be negatively correlated with the amount of anthropogenic materials and was significantly negatively correlated with total feather mass within a nest. However, there was no detected relationship between hatching success and the amount of unpigmented feathers within a nest. Along with there being no detected relationship between the amount of anthropogenic materials and fledging success among nestlings. Anthropogenic materials and feathers appeared to have adverse effects on nestling condition, so it is surprising that they are abundant in many of their nests.

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Introduction

Nests are important to many species of birds as they provide critical shelter for eggs and offspring. Nests differ among species and typically consist of natural materials such as grasses, various plants, twigs, flowers, and feathers (Ruiz-Castellano et al. 2018). Some species also add anthropogenic materials into their nests which can include various types of plastics, twine, string or ribbon, fabric, and paper (Townsend and Barker 2014). Additionally, cigarette butts have been found in various avian nests and are thought to decrease parasite abundance as they contain nicotine and other repellent chemicals (Suarez-Rodriquez et al. 2013), and potentially increase nestling success. Common anthropogenic materials found in shorebird nests located near bodies of water consist of fishing supplies (e.g. rope, lines, nets, and rope fibers), along with various types of plastics from both household and industrial use (Garcia-Cegarra et al. 2020).

A study by Garcia-Cegarra et al. (2020) examined two separate colonies of red-legged cormorants (*Phalacrocorax gaimardi*) and discovered that marine debris occurred in 100% of the 18 nests that were examined, with the most abundant plastic type consisting of polypropylene bulk bags (35%) and plastic bags (33%). Fishing supplies were the second most abundant type of anthropogenic material found (18%) followed by other various plastics (<2%) (Garcia-Cegarra et al. 2020). Anthropogenic materials have also been found in a variety of other avian species including albatrosses (*Thalassarche* spp.), brown boobies (*Sula leucogaster*), great frigatebirds (*Fregata minor*) and many others that nest in sites along shores (Battisti et al. 2019; Brentano et al. 2020; Luna-Jorquera et al. 2018).

The increase in anthropogenic materials observed in nests globally demonstrates that there is a consistent increase in the use of plastic and the dumping of garbage which add to the risk of entanglement and ingestion by avian species (Luna-Jorquera et al. 2018). There is a lack of research regarding how these anthropogenic materials that are incorporated into the nests of terrestrial passerine species are affecting nestling success (Hudecki et al. 2021). Townsend and Barker (2014) examined entanglement rates among nestlings within urban and agricultural American crows (*Corvus brachyrhynchos*) and reported that within 106 nests, 5.6% (11/195) of nestlings had become entangled in anthropogenic materials. They discovered that fledging success was significantly reduced for those entangled nestlings. The researchers then dissected 54 of the nests and found anthropogenic materials that were at least 10 cm in length in 46 (85.2%) of the nests with materials composed of mostly strings, twines, plastics, clothes, fishing lines, nets and mesh. Their findings also demonstrated that the chance of nestling entanglement increased with the length of anthropogenic materials in the nest (Townsend and Barker 2014). A study by Hudecki et al. (2021) examined the impact of plastic use by the loggerhead shrike (*Lanius ludovicianus*) in a grassland habitat and found that 20% of the 24 nests examined over two seasons (2013 and 2019) contained plastic debris with three instances of nestlings becoming entangled. European starlings (*Sturnus vulgaris*) are another passerine species that incorporates anthropogenic materials into its nest (Clark and Mason 1985), but nothing has yet been thoroughly documented in the literature on this behavior.

The European starling is an urban-thriving species that is also known as an urban exploiter (McKinney 2006). They are cavity-nesters, typically building in enclosed areas such as holes in trees or in old crevices (Feare 1984). Nests are constructed from both natural and anthropogenic materials located in the surrounding area (Clark and Mason 1985). Starling males typically begin building their nests in early spring (around April) adding greenery to attract females who will then help in building the nest (Clark and Mason 1985; Dunnet 1955). Two separate clutches are typically laid throughout the period between April and July (Dunnet 1955; Kessel 1957). Each clutch usually contains 3-7 eggs that are incubated by both parents for about 12 days before the nestlings hatch. After hatching, the nestlings remain in the nest until about 20 days old, being fed and having their fecal sacs removed by both parents until they fledge (Dunnet 1955). After the first brood fledges, the parents remove the nest and build a new one (Mazgajski et al. 2004), which reduces the number of ectoparasites and harmful bacteria present (Pacejka et al. 1996) and potentially increases fledging success. Many ectoparasite species are present in European starling nests and they have been documented in our population (Fairn et al. 2014).

Investigation of feather preferences for nest-building among passerine species is a growing area of research. Past studies on spotless starlings (*Sturnus unicolor*; Ruiz-Castellano et al. 2018) and barn swallows (*Hirundo rustica*; Peralta-Sanchez et al., 2011) revealed a preference for feather colour to incorporate in their nest with them preferentially selecting unpigmented over pigmented feathers. Selecting primarily unpigmented feathers could be adaptive; barn swallow nests that contained a higher number of unpigmented feathers had increased hatching success (Peralta-Sanchez et al. 2011). Spotless starlings also had a preference for unpigmented over pigmented feathers during the pre-laying stage of nest building, although the preference was not linked to whether they led to higher reproductive success (Ruiz-Castellano et al. 2018). The results from both studies suggest that the preference for unpigmented feathers is related to their antimicrobial properties (Peralta-Sanchez et al. 2011; Ruiz-Castellano et al. 2018) which are attributed to the microorganisms living on these feathers (Ruiz-Castellano et al. 2019). However, Stephenson et al. (2009) found that with tree swallows (*Tachycineta bicolor*), feathers lining the nest did not act as an ectoparasite barrier, but that they did have a positive relationship with nestling growth rates. Winkler (1993) also found this positive relationship between unpigmented feathers and nestling growth rates in tree swallows but noted that nests from which feathers were removed contained a significantly higher number of mites and lice. Järvinen and Brommer (2020) examining Eurasian blue tits (*Cyanistes caeruleus*) and Ruiz-Castellano et al. (2018) suggested that feather preference could also be related to sexual signaling to attract mates through nest ornamentation.

I propose to examine three different questions related to nest material preferences among passerines by examining them among the European starling. As the amount of anthropogenic materials in our environments increases, it is important to examine how they affect the species around us. My first objective is to document the number of starling nests that have anthropogenic materials incorporated into them and whether these materials impact nestling brood condition and fledging success. I predict that nests containing more anthropogenic materials will have a negative impact on both brood condition and fledging success. My second objective is to quantify the amount (mass) of unpigmented feathers in each nest and to determine if there is a positive relationship between it and hatching success. I predict that nests containing more unpigmented feathers will have higher hatching success. My third objective is to determine whether a relationship exists between the total mass of unpigmented and pigmented feathers within a nest and average brood condition within a nest. I predict that nests with more feathers will have nestlings in better condition. Knowing if anthropogenic materials, feathers and feather colour affect the reproductive success of European starlings is important in this time of global decline in bird populations (Rosenburg et al. 2019) as we can then apply that information to potentially help passerine species achieve greater reproductive success and recover their population numbers.

Methods

Data Collection – Field

The study site for this experiment was the campus of Saint Mary's University in Halifax, Nova Scotia (44.6313° N, 63.5815° W). The campus is approximately 80 acres in size and is located in an urban environment that has a substantial number of trees and other vegetation. The 42 nest boxes used are attached to deciduous trees and are a minimum of 2.5 m high off the ground. European Starlings lay two broods over a breeding season. Early broods typically occur from April through late May, whereas late broods occur from early June through the middle of July (Dunnet 1955; Kessel 1957).

I collected nests from 38 nest boxes over two separate broods (16 from early broods and 22 from late broods) during the spring and summer of 2021. I collected the nests after the nestlings had fledged (when they were about 21 days old) and before the parents removed the nest themselves (Dunnet 1955; Mazgajski et al. 2004).

I monitored the nests closely when the nestlings were nearing their hatching time, 12 days after the last egg was laid. I weighed nestlings using a Pesola spring scale to the nearest 0.5 g on days 5 and 11 of the nestling period (day 0 is the day of first hatch). I also measured their right tarsus length with Fowler Sylvac digital calipers to the nearest 0.01 mm. Siblings each received a different colored band on their left tarsus on day 5 for individual identification; this band was replaced on day 11 with a Canadian Wildlife Service Band (CWS) on the right tarsus for future identification if caught as an adult. Parents were also caught when their nestlings were between 5 and 14 days old using either a motrap (Stutchbury and Robertson 1986) or a Swiffer broom to cover the nest box hole after the adult went inside. Adults were weighed, had their tarsus length measured and were given coloured leg bands along with a CWS band if they did not already have them. Males were given a yellow plastic band on their right tarsus above the CWS band whereas females were given a pink plastic leg band. All adults were banded with two unique colour combinations on their left tarsus for individual recognition.

Data Collection – Lab

Nest collection and sieving followed the procedures of Fairn et al. (2014). I collected each nest (n = 38) and placed it inside a large plastic bag with a label indicating the nest box number and collection date. Each bag was placed inside a large freezer (-20°C) for storage until analyses began, anywhere from 1 to 6 months after being stored. I started by dividing the nest into different components for easier handling. I weighed each component on a Scout Pro SP202 scale to the nearest 0.01 g. I then rinsed the nest material with warm tap water running through a metal sieve. The top layer of the sieve had mesh that was ½ inch wide while the bottom mesh was 4mm to help separate the larger from the smaller nest material items. Individual feathers and anthropogenic materials were removed and sorted on a baking tray and were dried over 1-2 days at room temperature. I then counted and recorded the number of feathers and anthropogenic materials in each nest. I also documented whether the feathers were unpigmented or pigmented and identified the type of anthropogenic materials found. I weighed unpigmented, pigmented and anthropogenic materials separately for each nest and placed them into labeled sandwich bags in the freezer for potential future use.

Data Analysis

I used GraphPad Prism Software (version 6.0) to statistically analyze the data. I tested the data for normality using a d'Agostino and Pearson omnibus normality test. I analyzed normally distributed data with parametric statistics and non-normally distributed data with non-parametric statistics. I determined hatching success for each nest by dividing the number of hatched eggs by the total number of eggs laid. Nestling condition was assessed on day 11 of the nestling period by conducting a linear regression of mass against tarsus length for each nestling and using the residuals as an index of condition. Higher residual values represent nestlings in very good condition whereas low, negative residual values indicate nestlings in poor condition. I took an average of nestling condition for each brood. I compared hatching success and brood condition of early vs. late broods using two-tailed unpaired t-tests. I did a correlation analysis of brood condition vs. 1) mass of anthropogenic materials, 2) total nest mass, and 3) total mass of feathers. I determined fledging success for each nest by dividing the number of nestlings that fledged by the total number of nestlings that hatched. Then I did a correlation analysis of fledging success vs. mass of anthropogenic materials. Lastly, I did a correlation analysis of hatching success vs. 1) mass of unpigmented feathers and 2) mass of pigmented feathers. Results were considered significant when $P \leq 0.05$.

Results

Early vs. Late Broods

One hundred percent (16/16) and 95.45% (21/22) of nests in early and late broods respectively had anthropogenic materials incorporated into them. However, there was no significant difference in the amount of anthropogenic materials between early (1.29 grams ± 0.30) vs. late (1.31 grams ± 0.25) nests (t = 0.0348, df = 36, P = 0.97). Similarly, no significant difference was found in the total amount of feathers in nests between early (Mean ± SE: 2.19 grams ± 0.30) and late (2.50 grams ± 0.34) broods (t = 0.6565, df = 36, P = 0.52). A significant difference in hatching success existed between early and late clutches, with early clutches having significantly higher success (86.5% ± 3.1) than late clutches (73.1% ± 3.9; t = 2.524, df = 36, P = 0.02; Fig 1). Brood condition, although not significant, tended to be higher in early (0.75 ± 1.18) than late broods (-1.83 ± 0.83; t = 1.838, df = 36, P = 0.07; Fig 2).

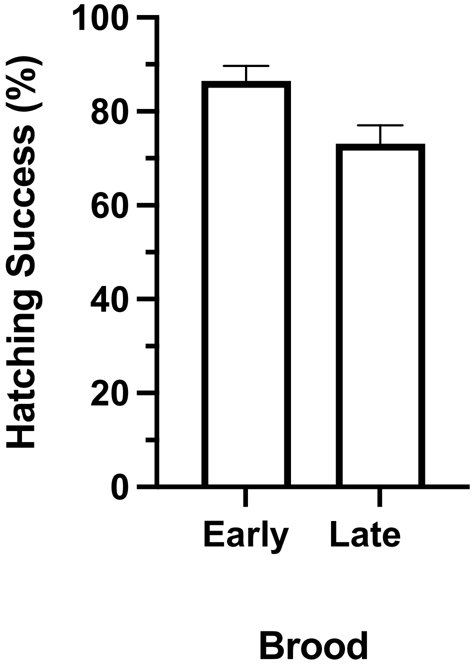

Figure 1. Percent hatching success ± SE for early (n = 16) and late (n = 22) clutches.

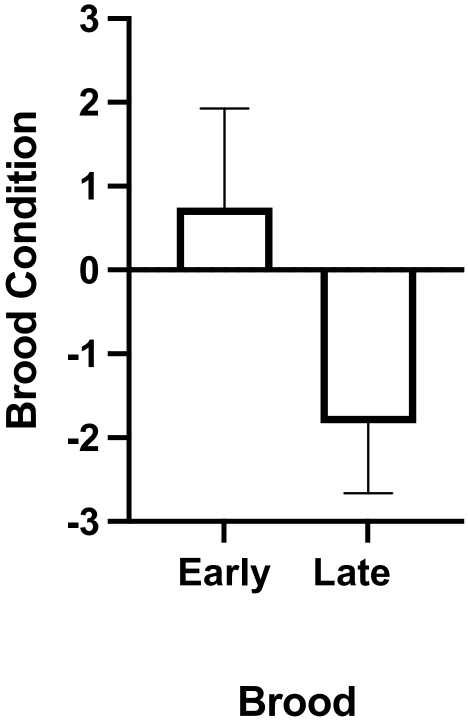

Figure 2. Mean brood condition ± SE for early (n = 16) and late (n = 22) broods.

Anthropogenic Materials

Brood condition tended to be negatively correlated with the total mass of anthropogenic materials in the nest (r = -0.3110, n = 38, P = 0.057; Fig 3). There was no significant relationship between total mass of anthropogenic materials in the nest and total nest mass (r = 0.0601, n = 38, P = 0.72; Fig 4). There was also no significant difference between fledging success and the mass of anthropogenic materials in the nest (r = 0.2091, n = 37, P = 0.21; Fig 5). The sample size was 37 instead of 38 for this result due to the uncertainty of fledging success from one nest.

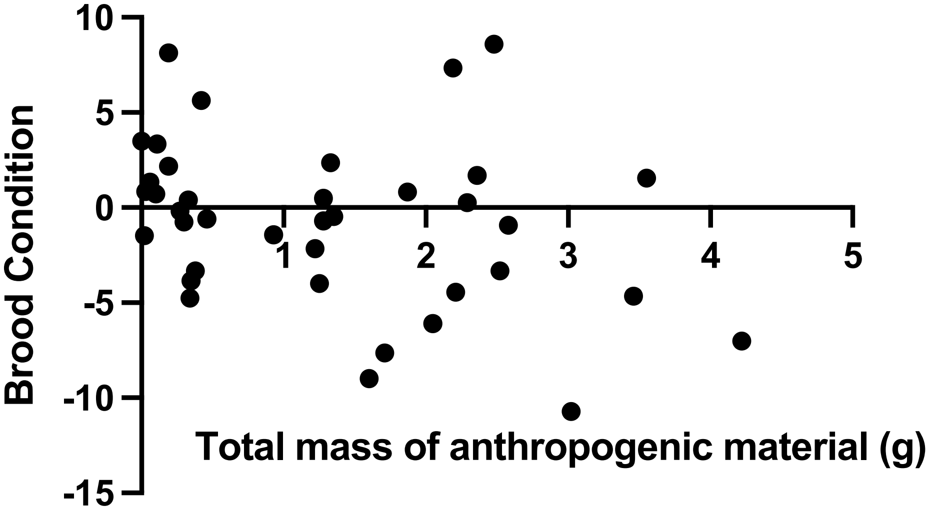

Figure 3. A scatterplot showing brood condition vs. the total mass of anthropogenic materials in each nest (n = 37).

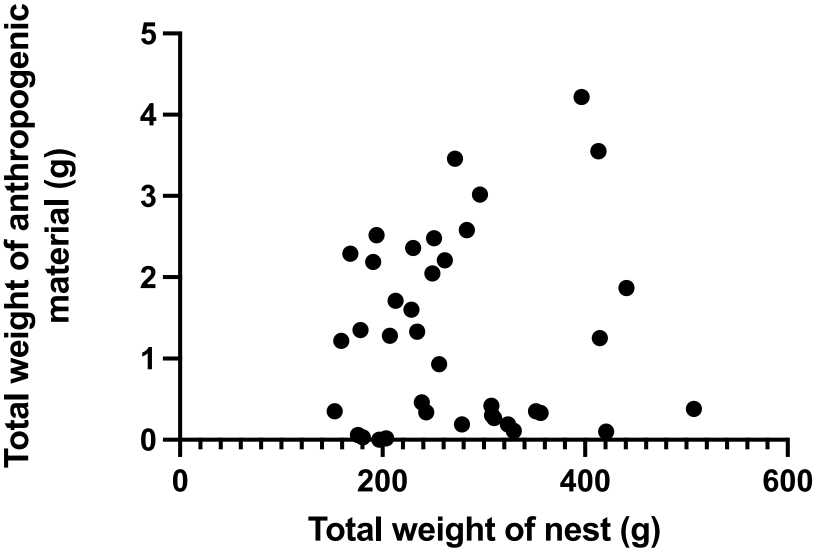

Figure 4. A scatterplot showing the total mass of anthropogenic materials in the nest vs. the total mass of the nest for all 38 collected nests.

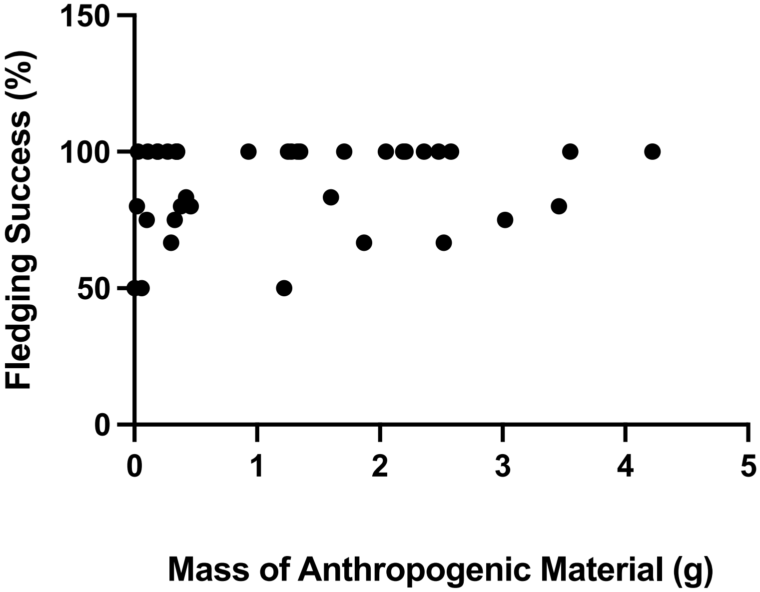

Figure 5. Scatterplot showing percent fledging success vs. total mass of anthropogenic materials for all 38 collected nests.

Total Nest Weight

There was no significant relationship between brood condition and total nest mass (r = -0.0867, n = 38, P = 0.60; Fig 6).

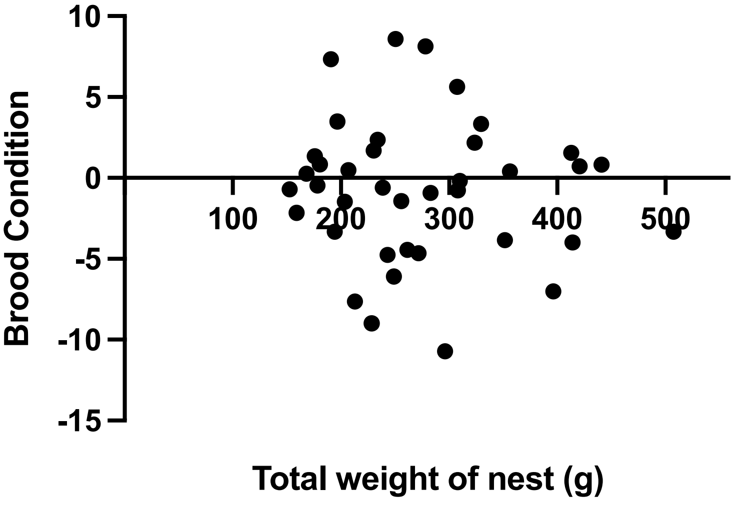

Figure 6. Scatterplot showing brood condition vs. the total mass of nest for all 38 nests collected.

Feathers

No relationship was detected between hatching success and the mass of unpigmented feathers in each nest (r_s = -0.0371, n = 38, P = 0.83; Fig 7). Similarly, when hatching success was compared with the mass of pigmented feathers in each nest, it also revealed no relationship (rs = -0.2427, n = 38, P = 0.14).

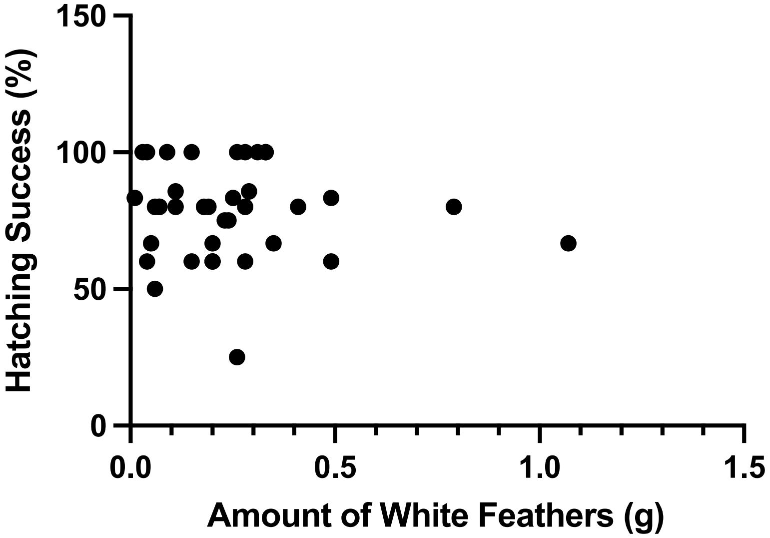

Figure 7. A scatterplot showing the percent hatching success vs. the mass of unpigmented feathers in the nest (n = 38 nests).

Finally, brood condition was negatively correlated with total feather mass in each nest (r = -0.4151, n = 38, P = 0.01; Fig 8).

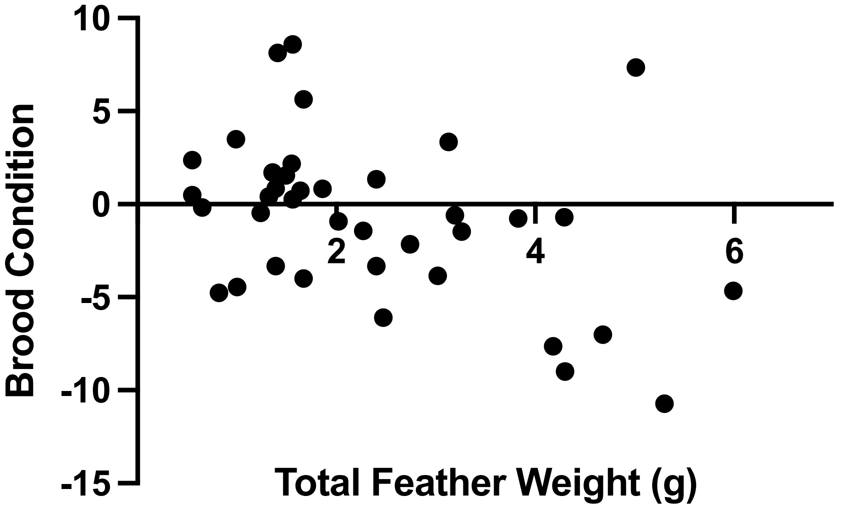

Figure 8. A scatterplot showing brood condition vs. total feather mass for all 38 collected nests.

Discussion

Anthropogenic Materials

The first of the three objectives I set out to examine was to document the number of nests that contained anthropogenic materials. As European starlings are known to add anthropogenic materials into their nests (Clark and Mason 1985), it was no surprise to discover that over both broods, 37/38 (97.37%) of nests had anthropogenic materials incorporated into them. Interestingly, no significant difference was detected in the amount of anthropogenic material between early and late broods and so it appears that human garbage is readily available and chosen throughout the breeding season. European starlings are urban thrivers (McKinney 2006) and so have adapted well to living alongside humans, even to the extent of inserting our garbage into their own nests.

As predicted, brood condition tended to be negatively correlated with the amount of anthropogenic materials within a nest, even though a statistical difference was not found. It is perplexing that European starlings and other avian species incorporate them into their nests. Proposed hypotheses to explain this behavior center around urbanization and human littering (McCleery et al. 2012). One hypothesis mentioned by Schuyler et al. (2012) is the possibility that these anthropogenic materials are mistaken as natural materials. An example is that of marine turtles *(Chelonia mydas* and *Eretmochelys imbricata)* who ingest plastic debris such as balloons, likely due to mistaking them for jellyfish, a natural food source (Schuyler et al. 2012). Another possibility is that there is a lack of natural materials within the surrounding environment, giving no other option but to use the anthropogenic materials as nest material (McCleery et al. 2012). Jagiello et al. (2019) examined 25 articles on anthropogenic material occurrence in avian nests that included 10,790 nests across 51 populations and reported that the incorporation of anthropogenic materials is positively correlated with the increasing influence humans have on the environment. This makes proper disposal of our garbage critical to decrease the occurrence of anthropogenic materials within avian nests, ensuring avian populations remain safe from potential ingestion or entanglement.

I found no support for my prediction that fledging success would be negatively impacted by the amount of anthropogenic materials present in the nest. In contrast, Townsend and Barker (2014) found that fledging success was significantly reduced in nests with anthropogenic materials due to nestling entanglement. The difference in our findings is likely due to nestling European starlings never having become entangled in anthropogenic materials in the year of this study. However, nestlings in poorer condition, although they can fledge, are at a disadvantage as studies have shown that condition at fledging is strongly associated with survival into independence (Naef-Daenzer and Grüebler 2016).

Feathers

I did not find support for my prediction of a positive relationship between hatching success and the mass of unpigmented feathers. A study done on barn swallows however did find such an association (Peralta-Sanchez et al. 2011). This unexpected result could be due to a lack of unpigmented feathers at the study site since the majority of other avian species in the city of Halifax are Rock pigeons (*Columba livia*) and American crows who do not have unpigmented feathers.

Also counter to my prediction, brood condition was not positively correlated with total feather mass but instead was significantly negatively correlated with total feather mass. This is surprising because of what was observed in previous studies (Stephenson et al. 2009, Winkler 1993) which was that nestling growth rates among tree swallows were positively related to the number of total feathers in the nest. Winkler (1993) proposed that feathers assist nestlings directly by providing thermoregulation benefits along with assisting indirectly by allowing for higher growth rates resulting in earlier fledging. Winkler (1993) found a benefit to nestlings having feathers within the nest up to a certain point in the nestling cycle; nests containing a large number of feathers did not influence nestling growth rates any further than nests containing less feathers past day 12 of the nestling period. Therefore, the presence of feathers within the nest might be beneficial for a limited time in nestling development. Future research on a larger scale is needed in this area of avian research to determine any conclusions on this theory.

Conclusion

In conclusion, populations of avian species are rapidly declining globally. A study analysis completed by Rosenberg et al. (2019) discovered that since 1970 there has been a loss of 2.9 billion breeding birds across North America. Knowing how anthropogenic materials affect surrounding wildlife is important as urbanization continues to increase. Jagiello et al (2019) demonstrated that the incorporation of anthropogenic materials is positively correlated with the increasing influence humans have on the environment. Proper disposal of our garbage is critical in ensuring avian populations remain safe from potential ingestion or entanglement. The knowledge gathered from this study on the effects of anthropogenic materials, feathers and feather color among European starling nestlings can be applied to other species to increase their reproductive success.

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Supplemental Information

Nestbox	Early Brood Hatching Success (%)	Nestbox	Late Brood Hatching Success (%)
4	85.7	1	25
8	80.0	2	66.7
9	100	3	66.7
14	80	5	80
20	100	12	80
22	100	15	100
28	80	16	60
33	83.3	20	60
34	60	21	60
36	100	22	83.3
37	100	26	75
40	85.7	27	50
44	66.7	29	80
45	100	30	100
46	80	32	100
49	83.3	33	80
		34	60
		36	100
		38	80
		39	60
		42	75
		49	66.7

Supplementary Table 1. Hatching success data for the early (n = 16) and late broods (n = 22).

Nestbox	Early Brood Residuals	Nestbox	Late Brood Residuals
4	-8.98	1	7.35
8	8.59	2	-4.66
9	-3.32	3	-3.33
14	1.35	5	-0.17
20	2.37	12	-3.99
22	5.63	15	-10.71
28	8.14	16	-7.63

33	3.34	20	-0.47
34	-1.42	21	-0.59
36	0.85	22	-4.45
37	-0.76	26	-2.15
40	0.25	27	3.49
44	-7.01	29	-1.47
45	2.18	30	-3.84
46	-0.93	32	0.40
49	1.69	33	1.55
		34	-6.10
		36	-4.77
		38	0.71
		39	0.83
		42	-0.69
		49	0.48

Supplementary Table 2. Mean brood condition residuals for the early (n = 16) and late broods (n = 22).

Nestbox	Early Brood Fledging Success (%)	Nestbox	Late Brood Fledging Success (%)
4	83.33	1	100
8	100	2	100
9	66.67	3	80
14	50	5	80
20	100	12	100
22	83.33	15	100
28	100	16	75
33	100	20	100
34	100	21	100
36	100	22	80
37	66.67	26	100
44	100	27	50
45	100	29	50
46	100	30	80
49	100	32	100
		33	75
		34	100
		36	100

		38	100
		39	75
		42	66.67
		49	100

Supplementary Table 3. Fledging success data for the early (n = 15), and late broods (n = 22).

Nestbox Number	Brood	Total weight of nest (g)	Total weight of material (g)
4	1	228.36	1.6
8	1	250.67	2.48
9	1	194.3	2.52
14	1	175.78	0.06
20	1	234.02	1.33
22	1	307.46	0.42
28	1	278.39	0.19
33	1	329.57	0.11
34	1	255.96	0.93
36	1	180.66	0.03
37	1	308.04	0.3
40	1	168.23	2.29
42	1	152.68	0.35
44	1	396.49	4.22
45	1	323.69	0.19
46	1	283.09	2.58
49	1	230.26	2.36
1	2	190.78	2.19
2	2	271.66	3.46
3	2	507.56	0.38
5	2	310.05	0.27
12	2	414.39	1.25
15	2	296.29	3.02
16	2	212.99	1.71
20	2	178.33	1.35
21	2	238.76	0.46
22	2	261.34	2.21
26	2	159.03	1.22
27	2	196.72	0
29	2	203.5	0.02

30	2	351.63	0.35
32	2	356.28	0.33
33	2	413.08	3.55
34	2	249.13	2.05
36	2	243.25	0.34
38	2	420.9	0.1
39	2	440.93	1.87
49	2	207.04	1.28

Supplementary Table 4. Anthropogenic material (g) and total nest weight (g) data for each nest (n = 38). Brood 1 indicates early brood; brood 2 indicates late brood.

Nestbox Number	Brood	Total Weight (g)	Unpigmented (g)	Pigmented (g)
4	1	4.3	0.29	4.01
8	1	1.56	0.07	1.49
9	1	1.39	0.09	1.3
14	1	2.4	0.19	2.21
20	1	0.55	0.03	0.52
22	1	1.67	0.26	1.41
28	1	1.41	0.28	1.13
33	1	3.13	0.49	2.64
34	1	2.27	0.28	1.99
36	1	1.39	0.09	1.3
37	1	3.83	0.33	3.5
40	1	1.56	0.11	1.45
44	1	4.68	1.07	3.61
45	1	1.55	0.33	1.22
46	1	2.02	0.41	1.61
49	1	1.36	0.25	1.11
1	2	5.01	0.26	4.75
2	2	5.99	0.2	5.79
3	2	2.4	0.35	2.05
5	2	0.65	0.06	0.59
12	2	1.67	0.07	1.6
15	2	5.3	0.31	4.99
16	2	4.18	0.49	3.69
20	2	1.24	0.2	1.04
21	2	3.19	0.2	2.99
22	2	1	0.01	0.99

26	2	2.74	0.24	2.5
27	2	0.99	0.06	0.93
29	2	3.26	0.79	2.47
30	2	3.02	0.15	2.87
32	2	1.32	0.28	1.04
33	2	1.49	0.18	1.31
34	2	2.47	0.15	2.32
36	2	0.82	0.04	0.78
38	2	1.64	0.11	1.53
39	2	1.86	0.04	1.82
42	2	4.29	0.23	4.06
49	2	0.55	0.05	0.5

Supplementary Table 5. Feather data containing total feather weight (g), unpigmented feather weights (g), and pigmented feather weights (g) for each nest (n = 38). Brood 1 indicates early brood; brood 2 indicates late brood.